In-situ Geochronology on the Mars 2020 Rover with KArLE (The Potassium-Argon Laser Experiment)

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Why KArLE?

A successful Mars exploration program has revealed chapters of Mars history, but in this book, the pages are ripped out of the binding and scattered across the surface. An examination of each page reveals interesting information, but there is no way to read the book in a logical order. Geochronology is the tool that puts page numbers onto the individual pages, and allows the book of Martian history to be read in its proper order. The KArLE experiment performs the first dedicated in situ geochronology investigation on Mars, bringing clarity to Mars 2020 samples and context to its landing site.

Science Goals and Objectives

The Potassium (K) - Argon (Ar) Laser Experiment (KArLE) addresses several high priority goals of the NASA Planetary Science Decadal Survey and Mars Exploration Program Analysis Group. Augmenting the anticipated suite of Mars 2020 baseline instruments, the KArLE science goals directly map to key Mars 2020 mission objectives. The proposed investigation goals are:

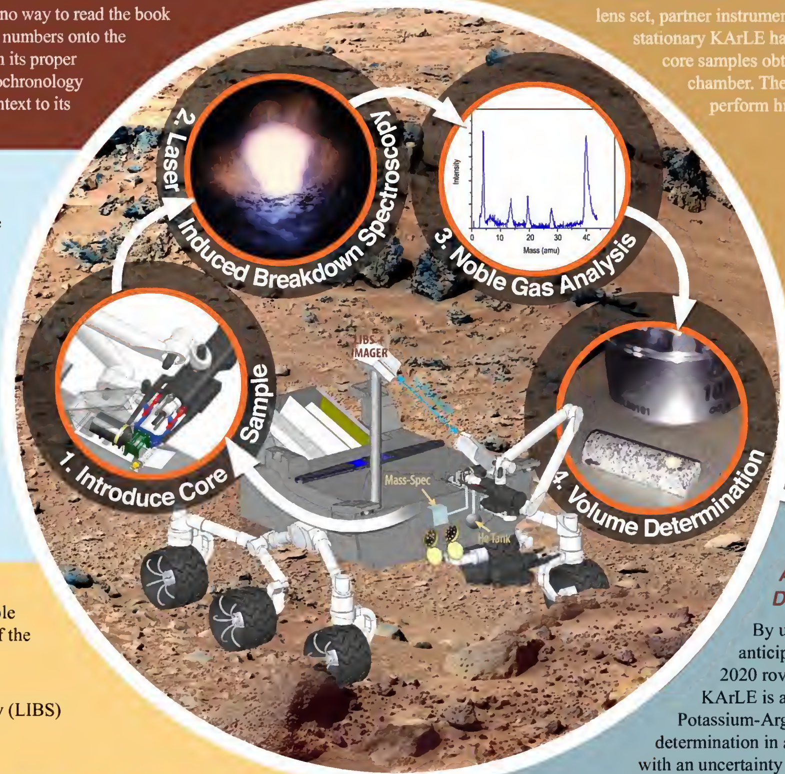
1. Determine the age of lithologic units investigated by the Mars 2020 mission to understand when they formed or underwent alteration on the Martian surface and how long they may have been energy sources for biological activity.
2. Add context to the geologic and biologic environment investigated by the Mars 2020 mission by using the age of local lithologic units to place them into planetary geologic, atmospheric, and climate history.
3. Use age information to help choose "scientifically selected, well-documented" samples to be cached for future return.

Investigation Overview

The KArLE experiment centers on a low-cost, mechanically simple chamber, and uses separate supporting instruments that are part of the anticipated Mars 2020 payload to make its analysis:

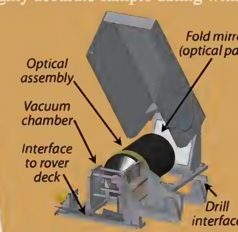
- Sample introduction via the coring/caching system
- Elemental analysis via Laser-Induced Breakdown Spectroscopy (LIBS)
- Noble-gas analysis via mass spectrometry (MS)
- Volume determination via optical imaging

The KArLE experiment is very flexible in its implementation and can be accomplished using any combination of these components, regardless of their specific provider.

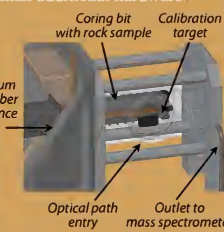


KArLE Hardware Overview

The KArLE investigation is designed to be a simple, robust augmentation to the anticipated baseline science instruments on the Mars 2020 rover. The hardware consists of a sample vacuum chamber, focusing lens set, partner instrument interfaces, and sample drill bits. Located on the rover deck, the stationary KArLE hardware interfaces with Mars 2020 baseline instruments to evaluate core samples obtained with the rover drill and delivered to the KArLE vacuum chamber. The proposed KArLE design provides a low cost, low risk approach to perform highly accurate sample dating with minimal additional hardware

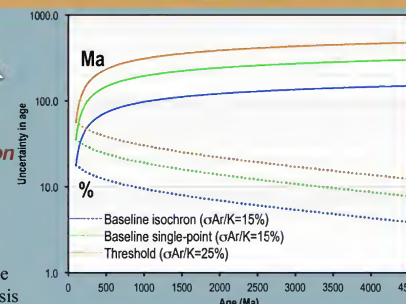


KArLE in the deployed position showing the chamber, optical assembly, fold mirror, and optical path for remote LIBS measurements and imaging.



KArLE chamber with bit/core sample inserted. Drill bit forces dust cover doors open. Hermetic seal formed between knife edge on chamber and soft metal on bit using axial force from arm

Age Determination



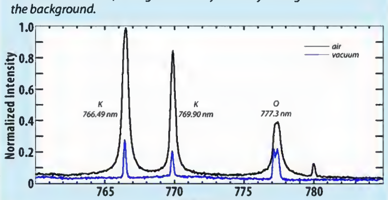
By using existing anticipated Mars 2020 rover resources, KArLE is able to make Potassium-Argon (K-Ar) age determination in a single analysis with an uncertainty < 300 Ma (green solid line) for the oldest rocks, with a baseline precision in the K/Ar ratio of 15%. By using an isochron approach, uncertainties < 10% (blue dashed line) should be achievable for all but the youngest rocks on Mars.

KArLE analysis methods have been developed, tested, and validated by three independent laboratories over 10+ person-years. Measurements using currently-available flight technologies are more than sufficient to achieve meaningful absolute ages.

2 LASER INDUCED BREAKDOWN SPECTROSCOPY (LIBS)

LIBS spectra are collected with every laser pulse and averaged over multiple shots. Spectra are corrected for background, normalized to total radiance, and continuum subtracted. [K] abundance is determined by peak area comparison with standards.

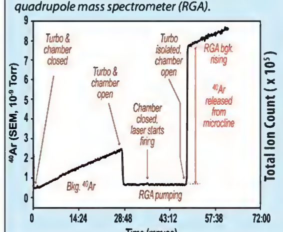
LIBS spectra of microcline showing K and O peaks in air and under vacuum (10^{-6} torr). LIBS intensity varies with confining pressure; however, even under vacuum, the signal intensity is clearly distinguished from the background.



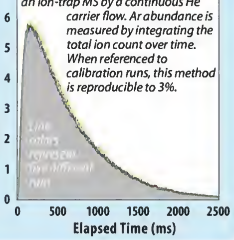
3 MASS SPECTROMETRY (MS)

Quantitative gas abundance can be measured by different kinds of mass spectrometers. ^{40}Ar levels in Martian samples are generally sufficient to measure against total gas pressure backgrounds of 10^{-6} torr with 500-750 laser shots/pit. The number of shots required is determined by the Ar abundance, a function of both [K] and age (older samples = fewer shots).

Ar gas released from the sample may be measured directly in static mass spectrometers, such as this quadrupole mass spectrometer (RGA).



Released Ar gas can also be measured dynamically. Aliquots are carried into an ion-trap MS by a continuous He carrier flow. Ar abundance is measured by integrating the total ion count over time. When referenced to calibration runs, this method is reproducible to 3%.



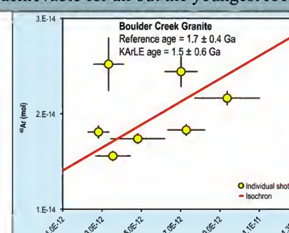
4 DENSITY (ρ) AND VOLUME (V)

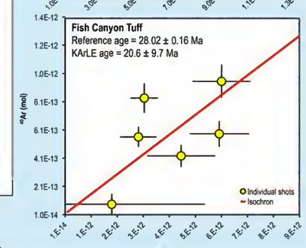
K and Ar abundances are related by sample mass. KArLE calculates mass using sample density based on elemental composition and volume by optical imaging, which is accurate to within 10% (French et al., this conference).

Keyence VX-200 laser scanning microscope, $V=7.5x10^7$ µm^3 | *Z-stacking 1.4 µm/pixel 100 µm DOF, $V=8.9 \times 10^7$ µm^3* | *Stereo Digital Elevation Map (DEM), $V=7.6x10^7$ µm^3, 50 µm/px areal, 8 µm/px vertical*

5 USING MEASUREMENT DATA TO DETERMINE AGE (t)

When a rock forms, different minerals have different parent abundances. As the rock ages, more and more daughter forms and the parent is used up. Measuring this ratio allows for dating.





KArLE breadboard results for Boulder Creek Granite and Fish Canyon Tuff verify its ability to accurately date geologic samples.

For these natural samples, we collected 200-500 simultaneous LIBS and MS measurements, along with pit volume measurement by laser confocal microscopy, downsampled to MAHLI resolution. We collected 6-7 individual spots to create an isochron. Results yield whole- rock ages within error of the accepted ages. The precision depends on blanks and calibration, both of which can be improved with preflight characterization.